Investigating the physics of plasma focus devices using computer vision

22nd Annual Signal & Image Sciences Workshop

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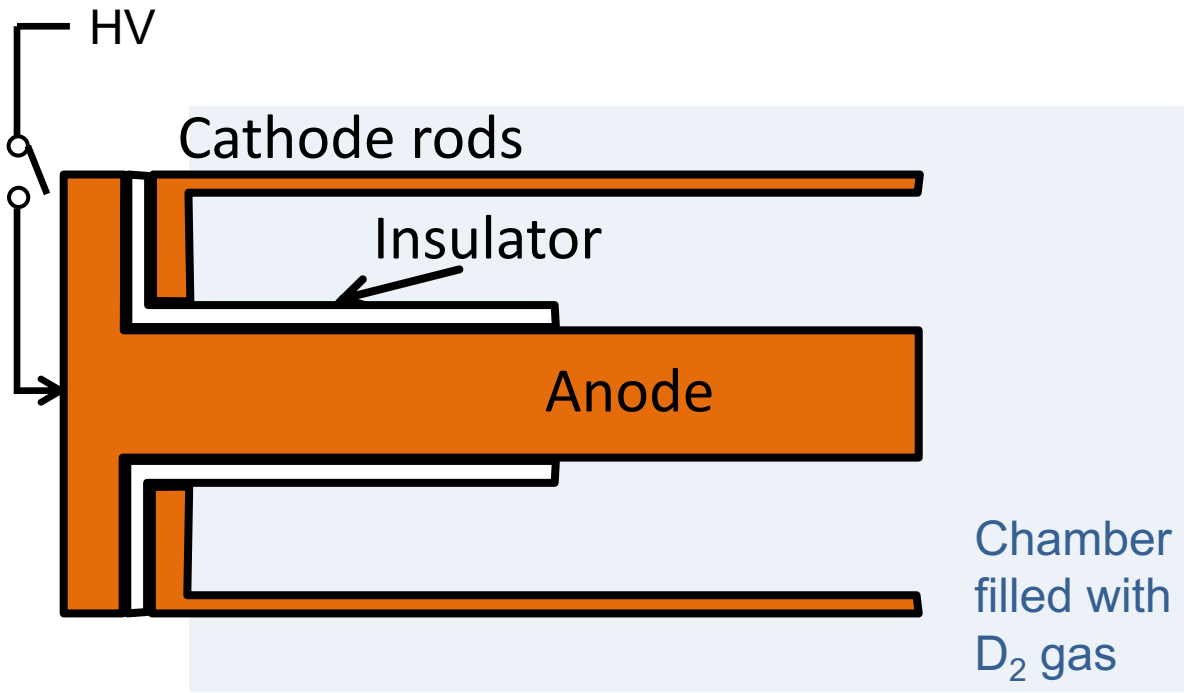
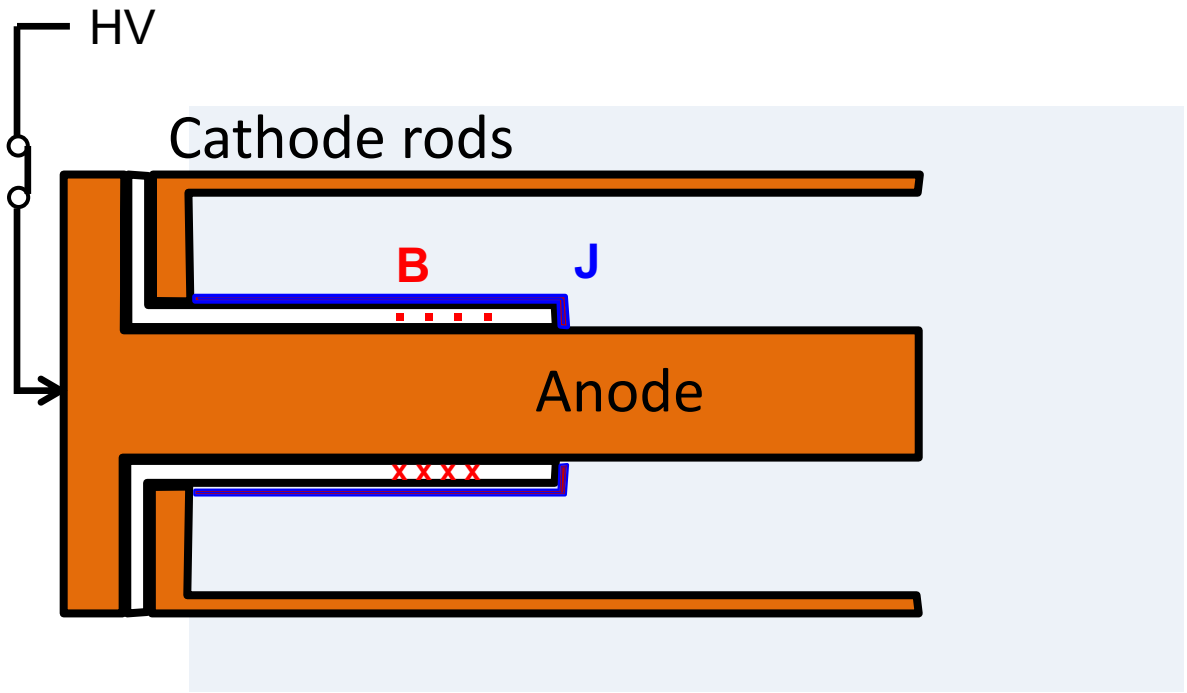
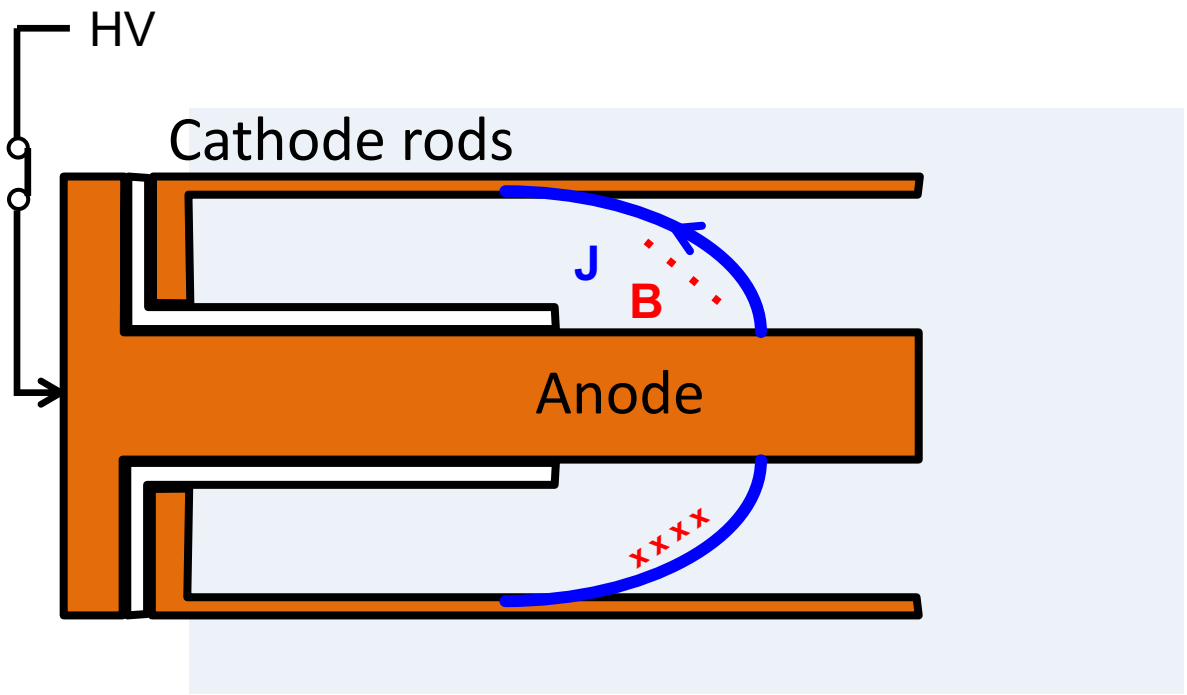
A Dense Plasma Focus (DPF) is a co-axial plasma rail gun generating short energetic neutron pulses



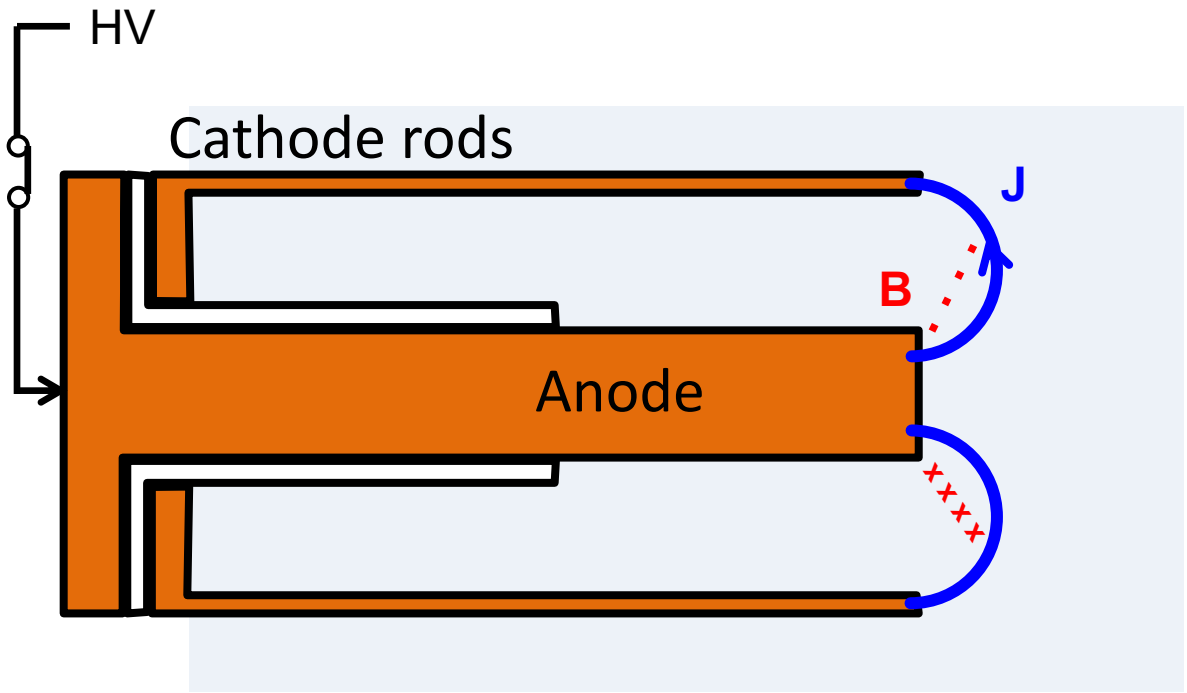
The high voltage discharge induces a breakdown inside the gas close to the insulator



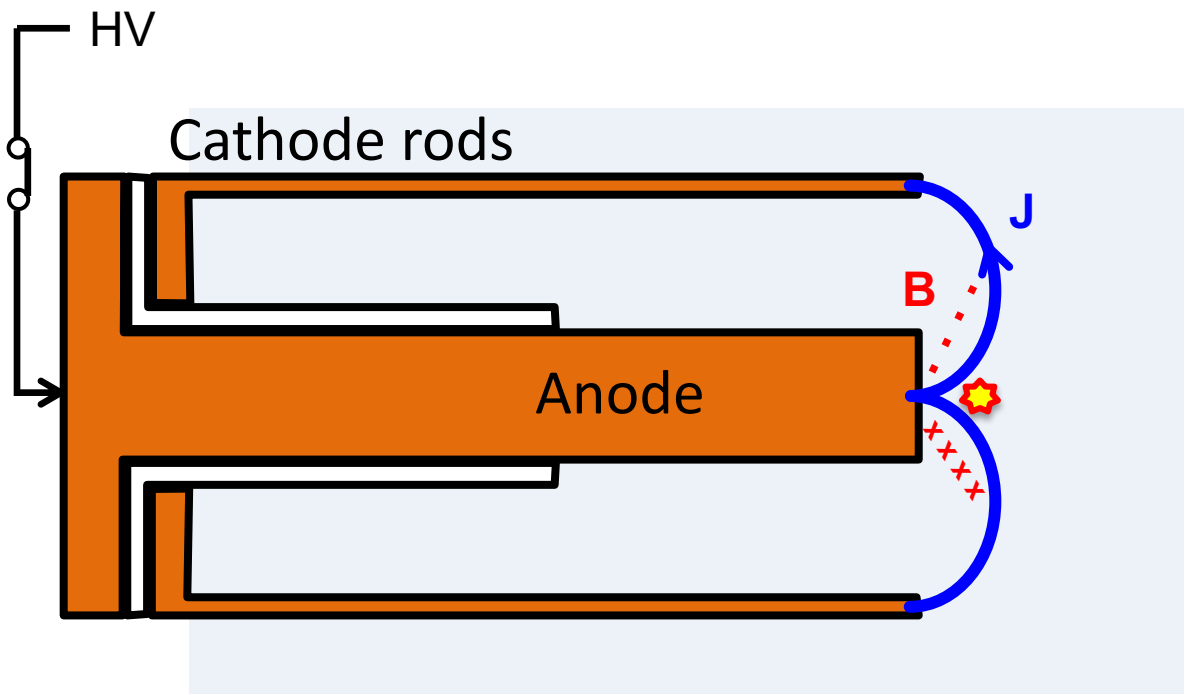
The current sheath lifts off the insulator and runs down the anode due to the magnetic pressure



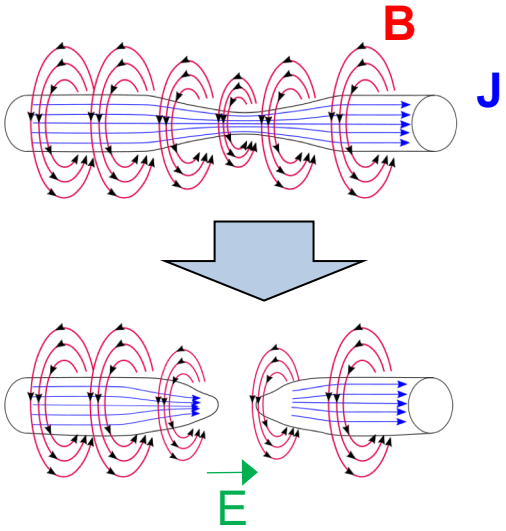
The sheath reaches the tip of the anode and start running inward



During the Pinch, large E-fields generate fast ions interacting with the high-density plasma to generate neutrons



E-field generation mechanism



(from $\frac{\partial B}{\partial t}$ and ∇n)

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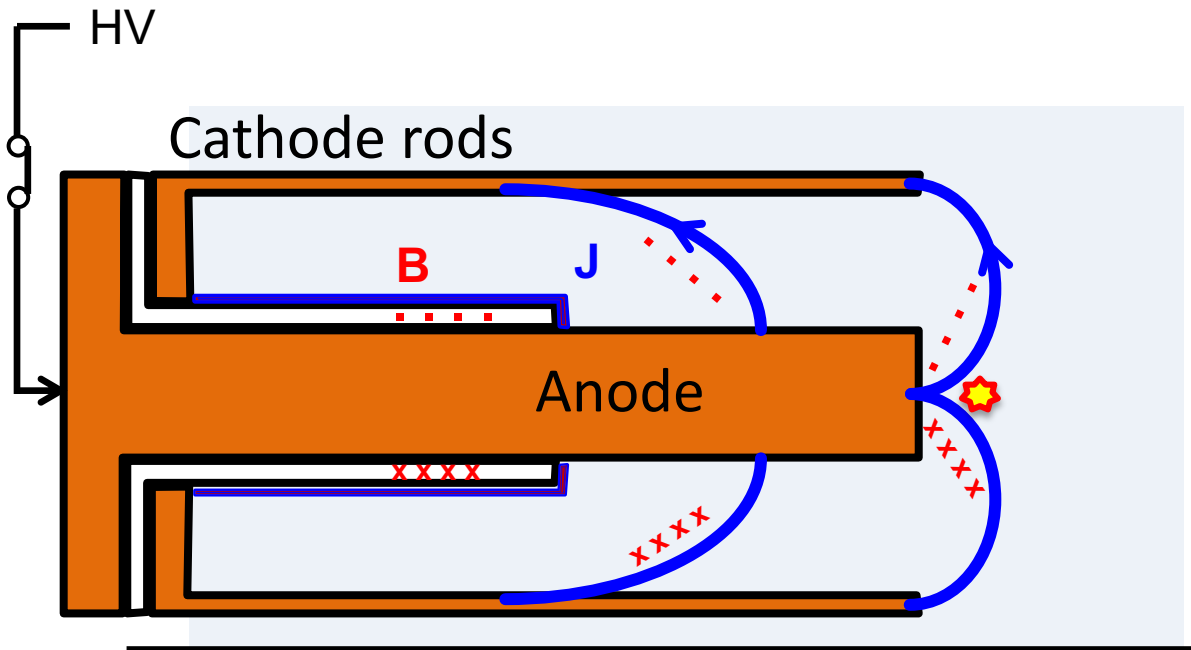
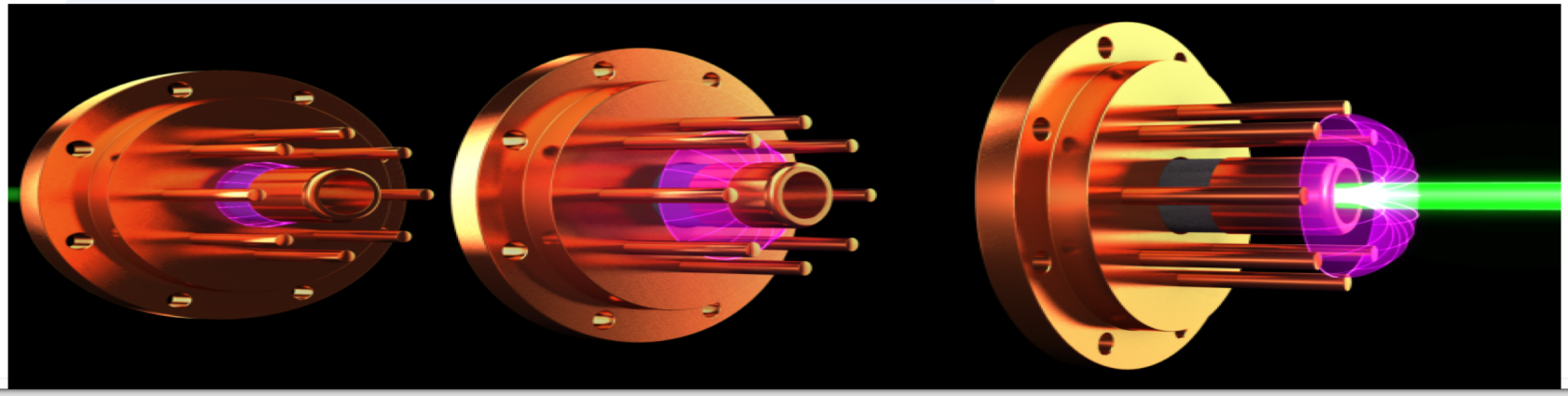
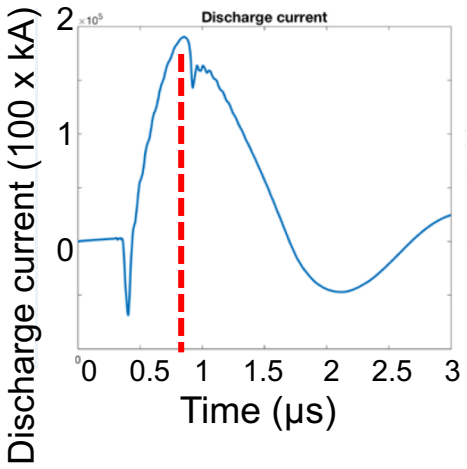
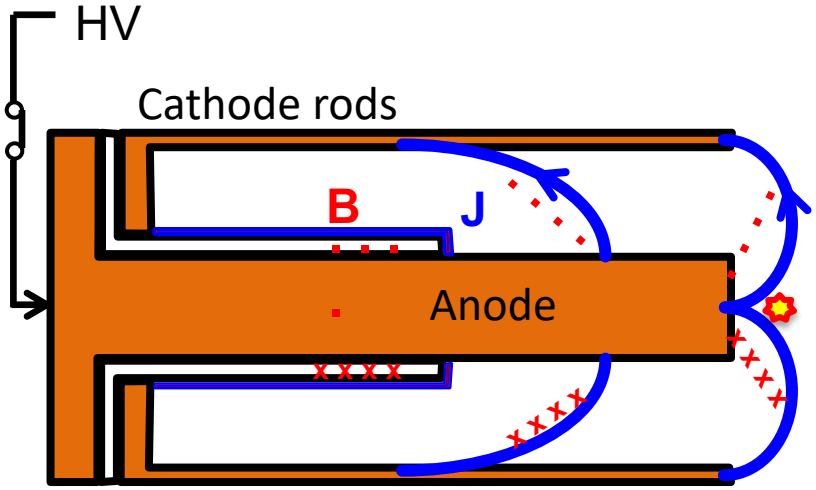




We measure the neutron yield, the current trace and images of the sheath run-in for up to 300 shots per day

current trace

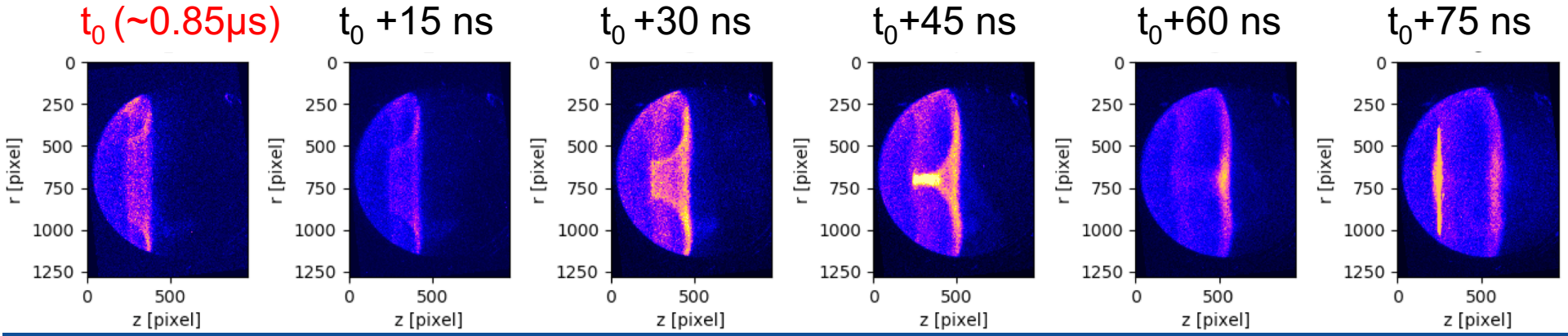




neutron yield

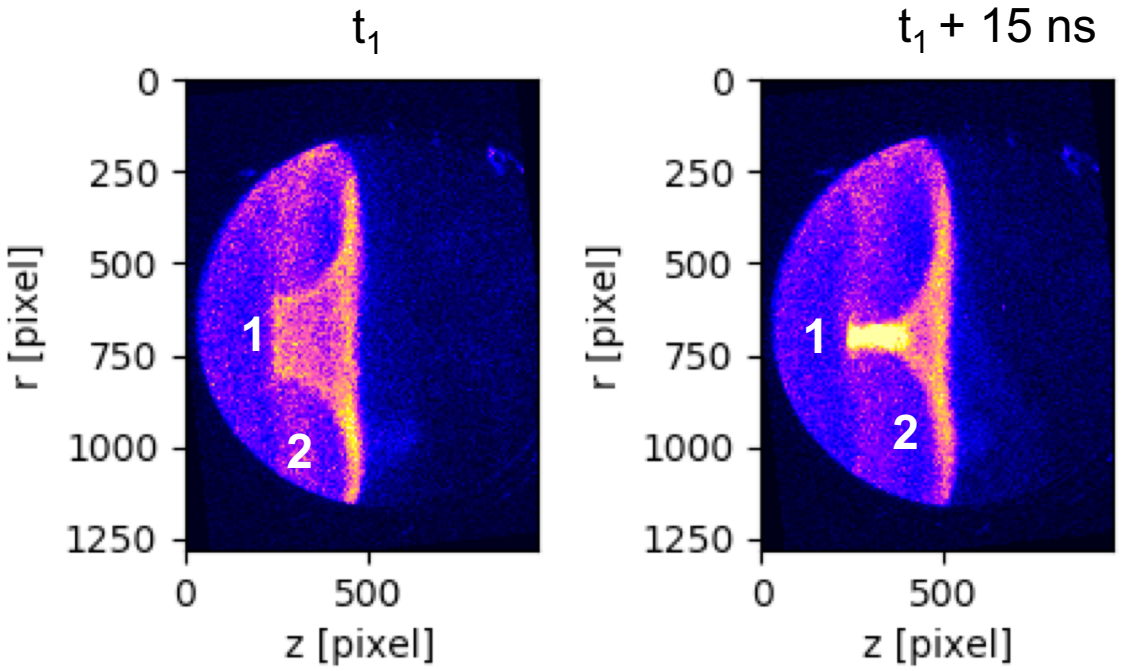
~10^7 neutrons per shot

run-in



=> The large amount of data requires to develop automatic analysis

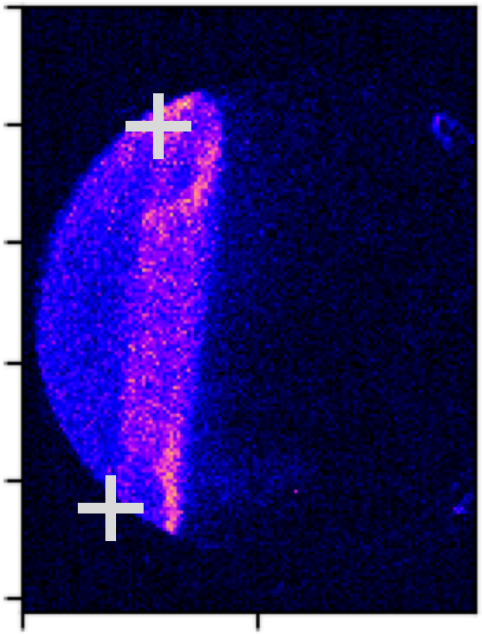
Images of the run-in contain a great deal of information about the physics of a DPF



1. Location of the pinch vs anode center
2. Shape of the sheath
3. Current ”re-strike”
4. Run-in velocity of the sheath

Step 1: Find the anode edges is manual but stays constant across a day of shooting

Defining anode location



Location of the two points at the anode edges is manually entered and will not change for a shot day. Also calculate the magnification of the image (convert pixel to mm)

Step 2: Rotate the images to have the anode vertical and smoothing using boxcar filter

Defining anode location

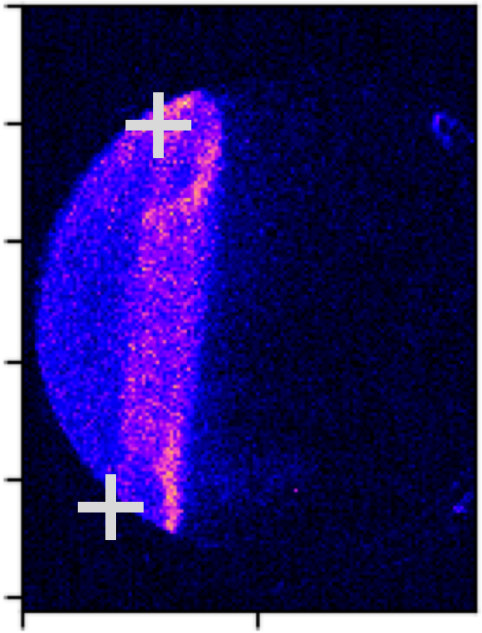
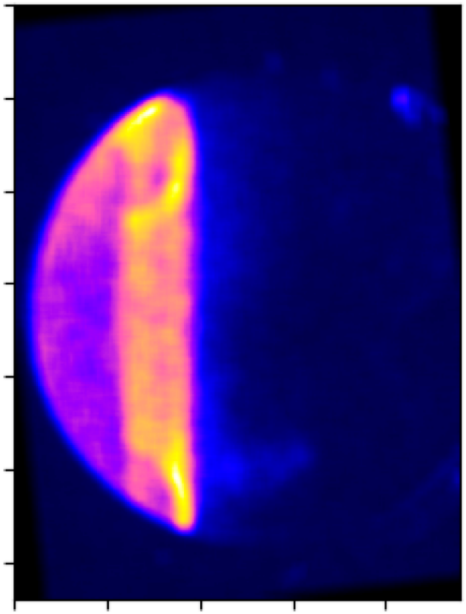


Image rotation and smoothing



Step 3: We track the sheath's edges as the extreme values of horizontal lineout's 1st derivative

Defining anode location

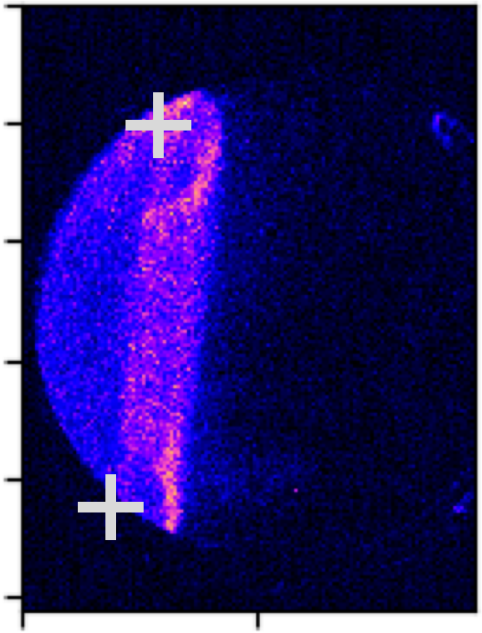
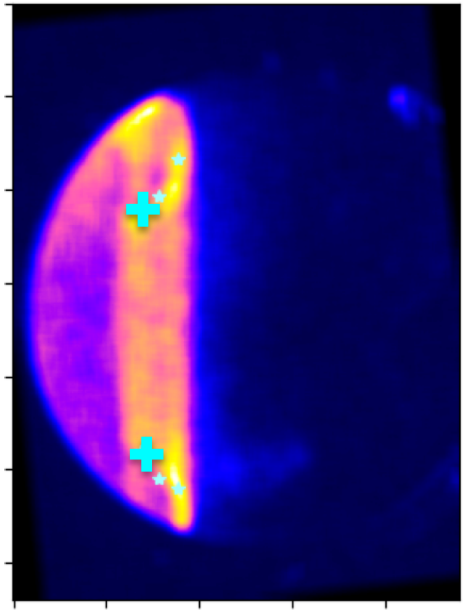
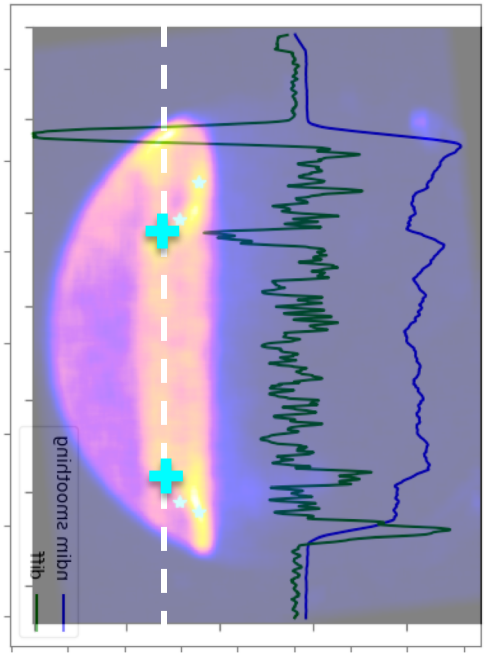


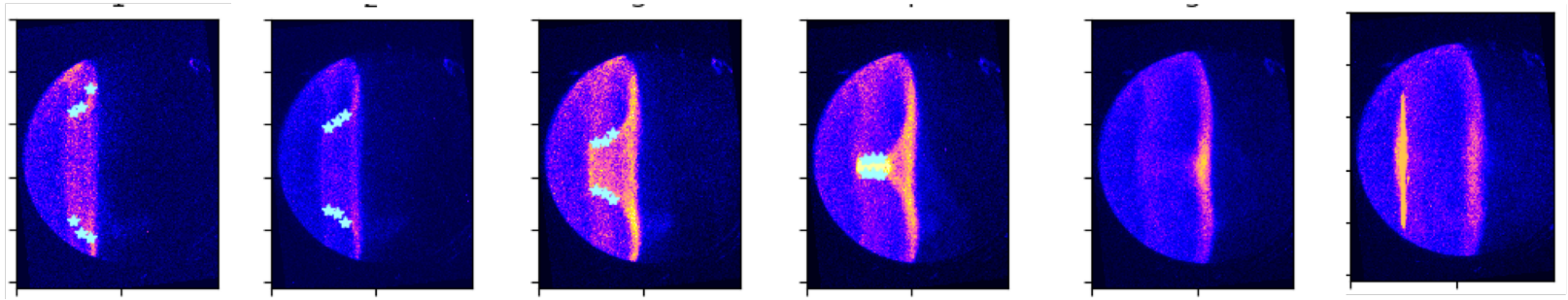
Image rotation and smoothing

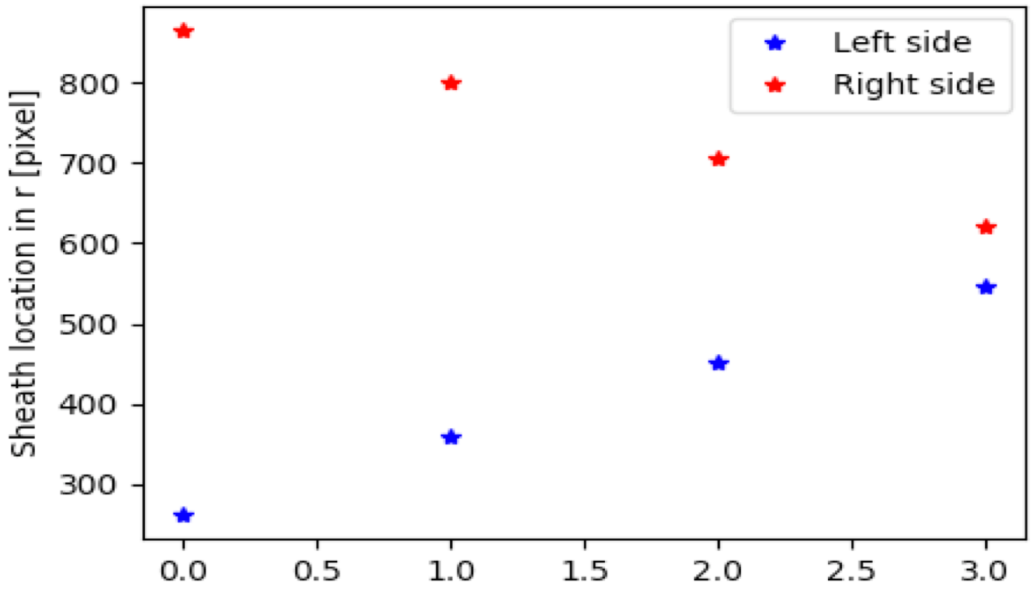


Sheath's edge detection



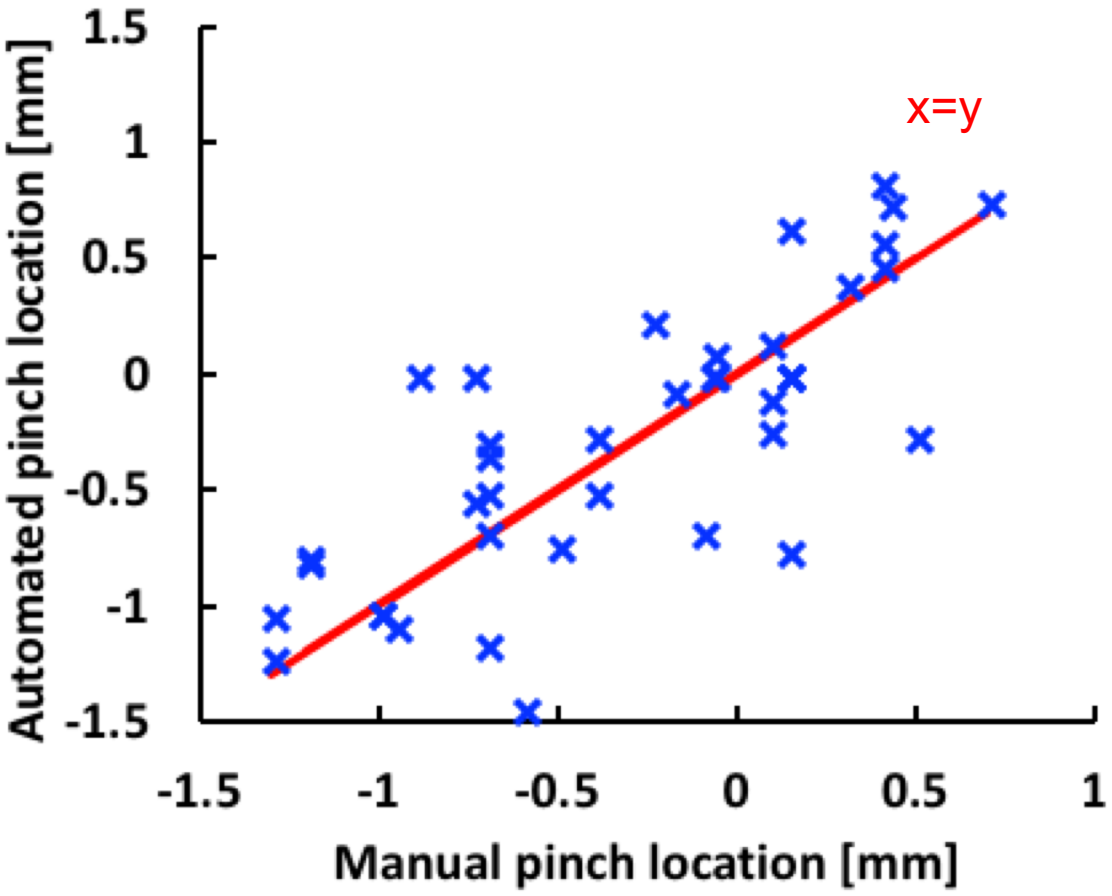
We can use several frame to track the pinch and the velocity of the run in



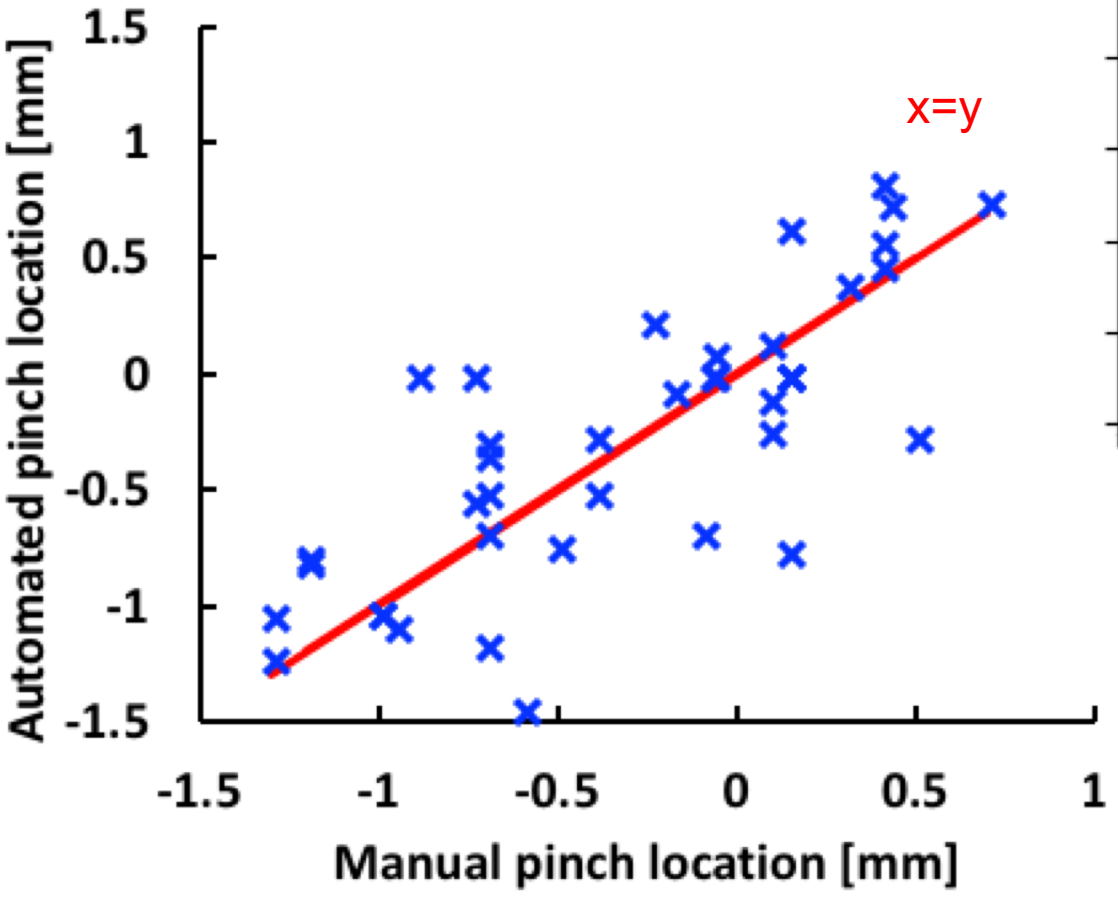


Finding the first frame after the pinch reproducibly can be really challenging

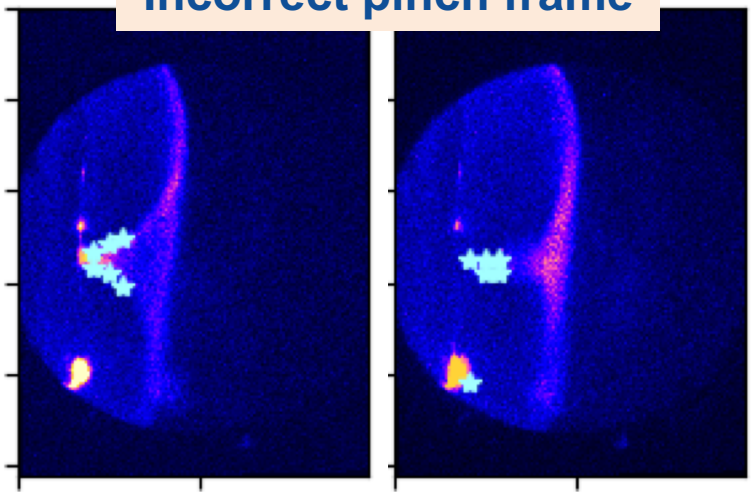
Automated analysis agrees well with location of the pinch



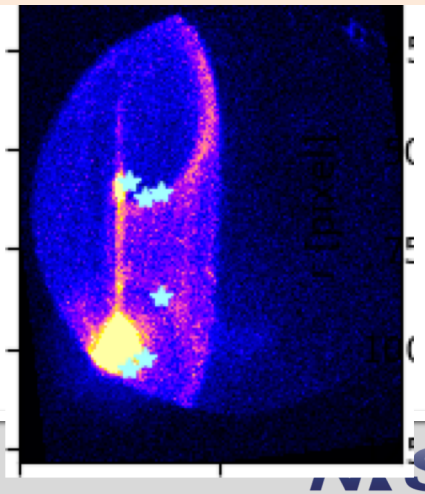
The outliers are explained by an incorrect tracking of the pinch frame or current re-strikes



Incorrect pinch frame



Re-strike



Conclusion

- We have developed a tool to automatically track the current sheath from fast framing camera data of a DPF
- Preliminary results suggest that the automated analysis is quite robust
- Work is currently undergoing to correlate pinch location and run-in velocity with the neutron yield
- We are considering improvements of the analysis routine:
  - more stringent test to identify the last frame before the pinch
  - fitting the shape of the frame

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